Cite this article
Argyroudis S, Wang X and Mitoulis S-A (2026)
Editorial: Whole-life thinking in bridge engineering.
Proceedings of the Institution of Civil Engineers – Bridge Engineering **179(4)**: 335–337,
https://doi.org/10.1680/jbren.2026.179.4.335

Editorial

Bridge Engineering

Editorial: Whole-life thinking in bridge engineering

Sotirios Argyroudis
Brunel University of London, London, UK; MetaInfrastructure.org, London, UK
Xiaowei Wang
Department of Bridge Engineering, Tongji University, Shanghai, China
Stergios-Aristoteles Mitoulis
Centre for Global Infrastructure Resilience, The Bartlett School of Sustainable Construction, University College London, London, UK; MetaInfrastructure.org, London, UK

1. Introduction

Bridge engineering is increasingly expected to do more with less – deliver adaptable structures, manage ageing portfolios, respond to changing hazards and justify interventions over decades of service. Meeting these demands requires more than isolated design checks or individual technologies. It calls for whole-life thinking, in which information, physical behaviour, recovery and investment are treated as connected parts of one decision process. Earlier contributions to this journal have argued that bridge performance should be understood not only through structural capacity, but also through transport-network functionality, restoration and adaptation (Argyroudis, 2022; Mitoulis *et al*., 2022). The papers in this issue advance that discussion through three linked themes: smarter design and prediction; response under dynamic and extreme actions; and renewal, resilience and long-term value (Figure 1).

2. Smarter design, prediction and asset intelligence

Whole-life decisions begin with information that can be reused rather than recreated. Yogeeswaran *et al*. (2026) present a workflow that converts Revit component families into Sofistik cross-sections through Rhino.Inside.Revit and the Sofistik–Rhinoceros interface, allowing geometric and finite-element models to be generated from a common parametric source. Its value lies in reducing duplicated modelling and supporting rapid reconfiguration, although reliance on several software platforms and initial scripting also illustrates the practical barriers to digital adoption.

Abdulameer *et al*. (2026) review 74 studies on neural-network prediction of bridge-pier scour. The review reports R^2 values above 0.9 and root mean square error reductions of 27–58% in selected case studies, but the paper's more important message concerns what is still needed: representative field data, robust validation, interpretability and closer integration of physical knowledge with data-driven models.

Modet Álamo *et al*. (2026) demonstrate this shift at network scale using Spain's national highway bridge stock. Their gradient-boosting model, developed from inspection, traffic, climatic and ground-condition data, reduced the mean absolute error by 40% relative to a naïve benchmark and showed strong ability to identify critical cases. However, missing construction dates and maintenance histories remain instructive. Asset intelligence depends as much on disciplined data governance as on sophisticated algorithms. These papers show that digitalisation should be judged not by model complexity, but by whether it improves information continuity and engineering decisions.

3. Bridge response under dynamic and extreme actions

The three papers on dynamic and extreme response remind us that efficiency in modelling must not obscure the mechanisms controlling behaviour. Jonsson (2026) explores a frequency-domain alternative to repeated time-history analyses of high-speed railway bridges. By representing an ensemble of HSLM-A trains through an envelope spectrum, the proposed method can estimate deck acceleration with fewer simulations while incorporating track load distribution, rail irregularities and, for integral portal frames, soil–structure interaction. The approach is deliberately exploratory, but it offers a useful route towards screening calculations and future load-model development.

Duranović and Meskell (2026) examine how bridge-deck overhang length changes vortex-induced vibration. Their computational study indicates that longer overhangs can reduce the maximum displacement amplitude and lock-in range by about 75%. However, it also identifies large-amplitude motion-induced oscillations and increased sensitivity to the assumed damping. A geometric feature that appears beneficial under one excitation mechanism may therefore activate another.

Li *et al*. (2026) investigate a five-span simply supported girder bridge with friction pendulum systems under travelling-wave earthquake excitation, including girder collisions. Although several response quantities approach uniform-excitation results as apparent wave velocity increases, collision forces may be seriously underestimated when wave passage is ignored. Across all three studies, secondary-looking choices – load representation, deck geometry, damping and spatial phase – can decisively affect

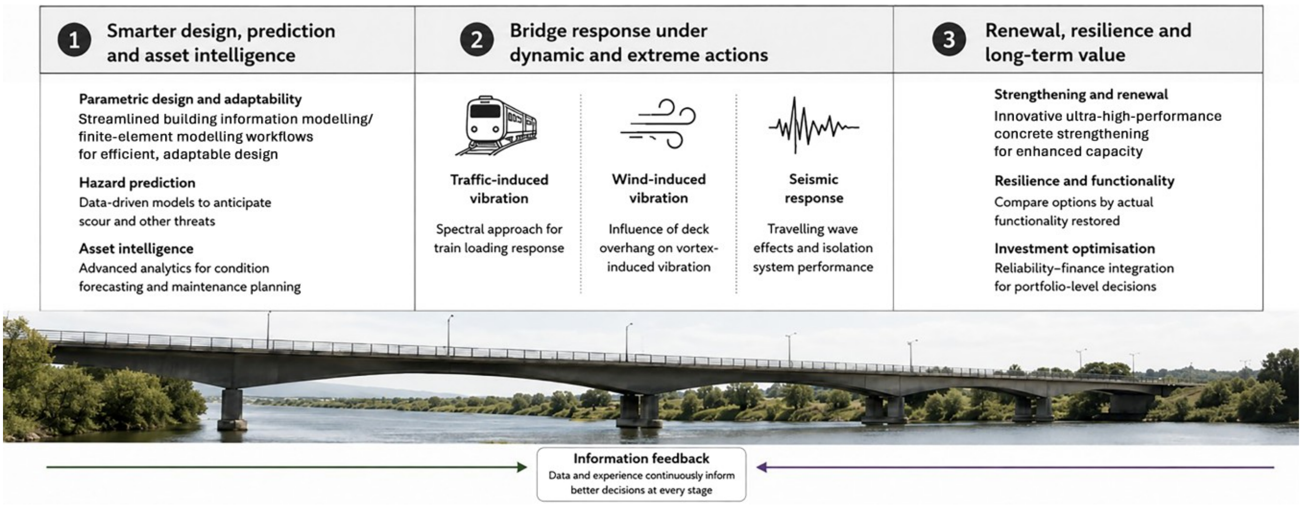

Figure 1. Thematic overview of the nine papers in this issue and their contribution to whole-life thinking in bridge engineering

design. Simplification remains valuable, but only when its limits and omitted mechanisms are transparent.

4. Renewal, resilience and long-term value

Renewal connects material intervention to restored service and public value. Shwalia and Al-Salim (2026) assess jointed and unjointed precast ultra-high-performance concrete layers, reinforced with glass-fibre-reinforced bars, for flexural strengthening of prestressed I-beams. The overlays increased the ultimate capacity by 82–112% and initial stiffness by 49–62%. Joints caused a modest capacity reduction relative to the continuous layer, but enabled segmentation of long strengthening elements and controlled failure location. Full-scale, fatigue and durability validation remain important next steps.

Collings (2026) widens the system boundary. Using ten bridge-collapse cases, the proposed method defines performance through functional units - road lanes, rail lines, footways, services and navigable waterways – both over and beneath the bridge. Reopening a route below a failed bridge may restore substantial functionality long before reconstruction is complete. The provisional weighting of unlike uses needs further development, but the framework makes interdependencies visible.

Finally, Kim *et al*. (2026) link time-dependent reliability to financial optimisation across an illustrative 20-bridge portfolio. Their mixed-integer framework uses an investment factor to balance initial resistance, life-cycle profitability and budget allocation, reporting a 2.97% profit increase or 5.05% cost reduction under alternative objectives. Because the case is synthetic and several financial variables are fixed, its results are methodological rather than prescriptive; nevertheless, it places a necessary question at the centre of bridge management – what combination of safety, functionality and long-term return should limited investment buy?

5. Conclusions

Taken together, these papers define whole-life bridge engineering in practice. Parametric design information should support later assessment; condition forecasts should guide inspection and maintenance; response models should isolate mechanisms threatening service; and strengthening, recovery and investment decisions should be judged by the functionality they preserve or restore. They also expose persistent barriers: incomplete records, model transferability, software interoperability, validation and assumptions about how services are valued. These are not reasons to retreat, but to make uncertainty explicit and retain engineering judgement within automated workflows. Lad and Patel's (2025) review highlighted the growing use of bridge-resilience frameworks while noting the concentration of research on seismic hazards. The contributions in this issue broaden that agenda, linking methods from component to portfolio scale. Progress will not come from choosing between physics and data, asset and network, or safety and economics, but from integrating them. A bridge should be viewed not only as a structure carrying loads, but as a changing, connected public asset whose performance, recovery and value must be managed together.

REFERENCES

Abdulameer L, Obaidi MA, Tuma Al-Awadi A *et al.* (2026) Optimisation of bridge scour depth prediction with neural networks: a comprehensive review. *Proceedings of the Institution of Civil Engineers – Bridge Engineering* **179(4)**: 357–378, 10.1680/jbren.25.00045.

Argyroudis SA (2022) Resilience metrics for transport networks: a review and practical examples for bridges. *Proceedings of the*

Institution of Civil Engineers – Bridge Engineering **175(3)**: 179–192, 10.1680/jbren.21.00075.

Collings D (2026) A method for resilience comparisons of bridges and viaducts. *Proceedings of the Institution of Civil Engineers – Bridge Engineering* **179(4)**: 452–457, 10.1680/jbren.25.00026.

Duranović M and Meskell C (2026) Effects of the overhang length on the vortex-induced vibration response of bridge decks. *Proceedings of the Institution of Civil Engineers – Bridge Engineering* **179(4)**: 405–421, 10.1680/jbren.24.00027.

Jonsson JO (2026) Approximate bridge deck acceleration response from train loading using a spectral approach. *Proceedings of the Institution of Civil Engineers – Bridge Engineering* **179(4)**: 394–404, 10.1680/jbren.23.00026.

Kim Y-G, Choe C-H, Yun G-Y *et al.* (2026) Pareto-optimal bridge investment: a reliability–finance integration framework. *Proceedings of the Institution of Civil Engineers – Bridge Engineering* **179(4)**: 452–469, 10.1680/jbren.25.00015.

Lad VH and Patel KA (2025) State-of-art review of resilience of bridges and bridge networks. *Proceedings of the Institution of Civil Engineers – Bridge Engineering* **178(3)**: 300–318, 10.1680/jbren.24.00014.

Li B, Zhang D, Zhang B, Lv G and Wang B (2026) Seismic response of a simply supported girder bridge with FPS under travelling wave effect. *Proceedings of the Institution of Civil Engineers – Bridge Engineering* **179(4)**: 422–433, 10.1680/jbren.25.00032.

Mitoulis SA, Domaneschi M, Cimellaro GP and Casas JR (2022) Bridge and transport network resilience – a perspective. *Proceedings of the Institution of Civil Engineers – Bridge Engineering* **175(3)**: 138–149, 10.1680/jbren.21.00055.

Modet Álamo A, Pertierra Rodríguez M, Arias Hofman G *et al.* (2026) Advanced data analytics for predictive maintenance of bridges on the Spanish national highway network. *Proceedings of the Institution of Civil Engineers – Bridge Engineering* **179(4)**: 379–393, 10.1680/jbren.25.00041.

Shwalia ASI and Al-Salim NHA (2026) Flexural strengthening of prestressed I-beams using jointed and unjointed precast UHPC layers. *Proceedings of the Institution of Civil Engineers – Bridge Engineering* **179(4)**: 434–451, 10.1680/jbren.25.00046.

Yogeeswaran K, Chen Q, Alam MS and Klassen D (2026) A streamlined parametric workflow for enhanced bridge structural design and adaptability. *Proceedings of the Institution of Civil Engineers – Bridge Engineering* **179(4)**: 338–356, 10.1680/jbren.25.00038.